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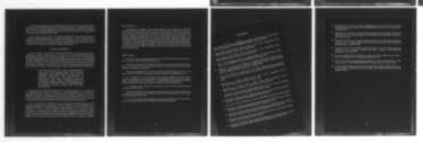

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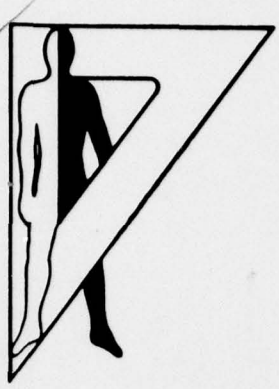

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Technical Note 13-78

HUMAN ENGINEERING DESIGN CRITERIA–THE VALUE OF OBSOLETE STANDARDS AND GUIDES

Gerald Chaikin

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November 1978
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U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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Careful assessment of the origin and intent of design provisions can take on added importance in light of current policies within the Department of Defense regarding tailoring of specifications and standards and reduction of interpretation stringency where marginal benefits of a standard requirement cannot rationalize cost-effective application to system needs. This report shows how tracing human engineering design criteria to determine validity and applicability, as developed from its sources, could become a useful technique and how the ancestors of current human engineering standards take on some value. The development of the current military standard for human engineering is also described.

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November 1978

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HUMAN ENGINEERING DESIGN CRITERIA—THE VALUE OF OBSOLETE STANDARDS AND GUIDES

INTRODUCTION

Human engineering design criteria, in the form of military and organizational standards, started appearing over twenty years ago. By 1968, the principal military standards for human engineering were consolidated as MIL-STD-1472 (Department of Defense, 1968) which has since been revised twice and has had two notices appended to the "B" revision.

Typically, the latest revision of a human engineering (or other) military standard is used for new contracts and programs and copies of the superseded edition are discarded, except when previously committed for use on continuing contracts and design efforts. Stock points eventually maintain a supply of only the latest revision—either because of policy or of inability to reorder copies of the superseded version as stocks are depleted. As time goes by, copies of the superseded standard become progressively more difficult to obtain. As we shall see, retention of obsolete human engineering standards can be of value beyond mere historical interest.

When a military standard for human engineering design is superseded, it becomes a link in a series of standards which one can use as a tool to trace the development of a specific provision in terms of identifying initial effectivity date, determining the original intent, noting changes implemented in the interest of maintaining harmony among a wide body of users and reviewers, detecting errors in retranscribing from revision to revision, correlating unchanged dimensional criteria against the most recent anthropometric data, and in many instances, identifying the original source document or research from which the provision was developed.

The use of obsolete human engineering standards to trace the origin and intent of design criteria, as well as for other purposes noted above, takes on added value in light of Department of Defense (DoD) policies announced last year regarding specifications and standards application. Briefly stated, the steps of the application and tailoring process for specifications and standards, as prescribed by DoD Directive 4120.21 (Department of Defense, 1977), consists of (1) selection of documents having potential application to a specific procurement, (2) reviewing these potential documents to select only those clearly applicable to a contract, (3) imposing only the minimum necessary requirements, and (4) examining the surviving requirements to tailor or adjust the provisions so that they support the particular system involved.

It is in this final area where traceability of human engineering requirements, to determine their validity as developed from their sources, becomes important and where obsolescent human engineering standards can take on some value. From the point of view of the contractor upon whom the human engineering standard is imposed, the same DoD Directive states, "Beneficial recommendations from prospective contractors shall be solicited to determine whether additional cost-effective application and tailoring of cited . . . standard . . requirements can be accomplished or cost-effective substitutions proposed." Here is where tracking a standard human engineering provision back through its sources can become a valuable technique to evaluate the validity or intent of a specific requirement for potential modification or tailoring to system performance objectives.

BRIEF HISTORY OF MILITARY STANDARDS FOR HUMAN ENGINEERING

Development

Before exploring some examples of tracking human engineering provisions of current standards through predecessor documents, consideration of the "road map" of human engineering standards leading to the current version of MIL-STD-1472 might serve as useful background. This is presented in Figure 1.

Air Force Military Standards

Considering only those military and agency human engineering standards applied on a multicontract basis, it appears that the initial standards in this area were used by the Air Force with publication of WDT Exhibit 57-8, released 1 August 1957, updated 1 March 1958 and revised 1 November 1958, as AFBM Exhibit 57-8A "Human Engineering Design Standards for Missile System Equipment," (US Air Force, 1958).

AFBM Exhibit 57-8A drew much of its material from information contained in fourteen guidance and source documents listed in the exhibit, including three publications which had been prepared as Chapters II, V and VI of the Joint Services Human Engineering Guide to Equipment Design. AFBM Exhibit 57-8A and the subsequent standards we will be discussing are based, in part, on 142 guidance and source documents identified in the "guidance document" section of each standard. While space limitations of Figure 1 preclude showing these 142 sources as inputs to the standards shown, it is important to highlight that a considerable portion of source material used in human engineering military standards can be readily identified.

MIL-STD-803

On 5 November 1959, MIL-STD-803 (Department of the Air Force, 1959) superseded AFBM Exhibit 57-8A and represented the first military standard for human engineering design. Its scope of application was changed from missile system equipment to aircraft, missile and space systems ground support equipment. MIL-STD-803 was basically AFBM Exhibit 57-8A, reformatted as a military standard with some minor additional definition and self-containment. All eleven source/guidance documents of MIL-STD-803 were common with those of AFBM Exhibit 57-8A.

MIL-STD-803A1

On 27 January 1964, MIL-STD-803A1 (USAF), "Human Engineering Design Criteria for Aerospace Systems and Equipment," (Department of the Air Force, 1964) superseded MIL-STD-803. This was the first of a series of three parts to be issued. The second and third parts were directed toward aerospace system facilities and aerospace vehicles.

MIL-STD-803A1 was a rather extensive revision and update of MIL-STD-803. Where possible, criteria was quantified; e.g., "sufficient" clearance around indicator lights became a minimum of 3/4-inch clearance. Additions included provisions for large scale displays; a section on auditory displays; anthropometry data tables for both standing and seated body dimensions; figures on work positions and clearance dimensions; and new criteria for handle and grasp area

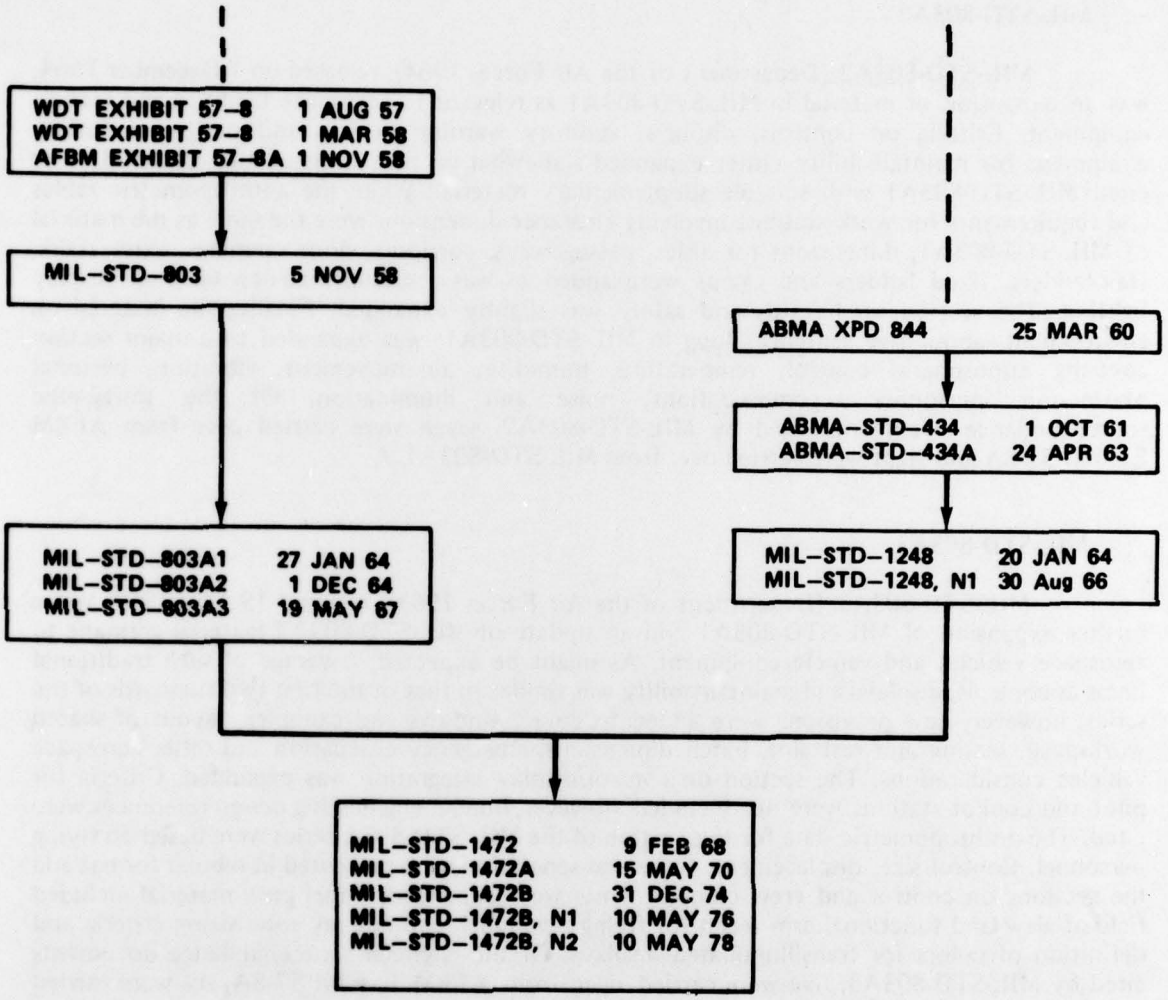

Figure 1. Development of MIL-STD-1472.

dimensions, equipment colors, design of equipment for remote handling and operational and maintenance vehicles. Of the twenty-six source/guidance documents used by MIL-STD-803A1, seven were carried over from AFBM Exhibit 57-8A.

MIL-STD-803A2

MIL-STD-803A2 (Department of the Air Force, 1964), released on 1 December 1964, was an expansion of material in MIL-STD-803A1 as relevant to aerospace facilities and facility equipment. Criteria on controls, displays, auditory warning devices and design of facility equipment for maintainability either expanded somewhat on provisions of MIL-STD-803A1 or cited MIL-STD-803A1 with suitable supplementary material. While the anthropometric tables and requirements for work stations involving clearance dimensions were the same as the material of MIL-STD-803A1, dimensions for aisles, passageways, corridors, door openings, exits, stairs, stair-ladders, fixed ladders and ramps were added as was a section and new table on display lighting. The section on hazards and safety was slightly expanded. Finally, the material on environment—about five sentences long in MIL-STD-803A1—was expanded to a major section covering atmospheric control, temperature, humidity, air movement, vibration, personal protection, personnel accommodations, noise and illumination. Of the thirty-nine source/guidance documents cited by MIL-STD-803A2, seven were carried over from AFBM Exhibit 57-8A and eight were carried over from MIL-STD-803A1.

MIL-STD-803A3

MIL-STD-803A3 (Department of the Air Force, 1967), released 19 May 1967, was a further expansion of MIL-STD-803A1 and an update of MIL-STD-803A2 material germane to aerospace vehicles and vehicle equipment. As might be expected, coverage of such traditional items as controls, displays and maintainability was similar to that of the first two standards of the series; however, new provisions were added to cover windows and canopies, layout of shared workspace, seating and restraint, hatch dimensions, emergency evacuation and other aerospace vehicles considerations. The section on control/display integration was expanded. Criteria for pilot and copilot stations were not included; however, human engineering design references were cited. The anthropometric data for this section of the MIL-STD-803A series were based on flying personnel. Control size, displacement, force and separation were presented in tabular format and the sections on control and crew compartments were expanded. Other new material included field-of-view and functional arm reach for flying personnel, cathode-ray tube sizing criteria and definition of colors for transilluminated displays. Of the eighteen source/guidance documents cited by MIL-STD-803A3, five were carried over from AFBM Exhibit 57-8A, six were carried over from MIL-STD-303A1 and three were carried over from MIL-STD-803A2.

Army Military Standards

At this point, it is convenient to backtrack a few years to trace the development of the organizational and military standards generated by the Army since these documents were consolidated with the MIL-STD-803A series to become MIL-STD-1472.

ABMA-STD-434

As noted in Figure 1, the Army's initial multi-application human engineering standard appears to have been ABMA-STD-434, "Weapon Systems Human Factors Engineering Criteria" (Army Ballistic Missile Agency, 1961), issued 1 October 1961. This agency document was a direct descendent of ABMA-XPD-844, "PERSHING Weapon System Human Factors Engineering Criteria" (Army Ballistic Missile Agency, 1959). Although the title of ABMA-STD-434 implied wide application, its scope was directed toward development of ballistic missile and free flight rocket systems. The fifteen cited sources from which much of the material in ABMA-STD-434 was drawn included chapters II, V, VI, VII and VIII of the Joint Services Human Engineering Guide to Equipment Design. Some coverage of ABMA-STD-434 was fairly similar to that of MIL-STD-803—probably because the control, display and work space criteria sources used to compile them were the same.

Salient departures from what was contained in MIL-STD-803 included use of anthropometric data based on surveys of the Army population, provision for 5th and 95th percentile data for personnel garbed in arctic clothing, sound pressure limits based on criteria developed for PERSHING, and use of equipment colors tailored for Army equipment (although the colors for panels and labeling were adapted from those used by the Air Force). In many instances, references to the chapters of the Joint Services Human Engineering Guide to Equipment Design were cited as general guidance, supplemented by suitable detail.

ABMA-STD-434A

ABMA-STD-434A (Army Ballistic Missile Agency, 1963), revised a very small portion of the material in the basic issue of the standard. Weight lifting limits were modified from those based on height of lift to a fixed weight, the maximum noise limits were deleted in favor of referencing HEL-STD-S-1-63, "Noise Limits for Army Materiel Command Equipment" (Chaillet, 1963), and ventilation requirements were stipulated to maintain concentrations below threshold limit values specified by the American Conference of Governmental Industrial Hygienists. Of the fifteen source/guidance documents cited by ABMA-STD-434A, thirteen were carried over from ABMA-STD-434.

MIL-STD-1248

ABMA-STD-434A and MIL-STD-1248 (Department of Defense, 1964) were sufficiently similar, as was the case with AFBM 57-8A and MIL-STD-803, to be considered almost the same documents. MIL-STD-1248 was merely an upgrading of ABMA-STD-434A to military standard book format. In the process, the title was changed to, "Missile Systems Human Factors Engineering Criteria," more accurately designating the intended scope of the standard. Source/guidance documents were unchanged.

MIL-STD-1248, Notice 1

Notice 1 to MIL-STD-1248 (Department of Defense, 1966) modified the Army's human engineering design standard to a greater degree than elevating ABMA-STD-434A to MIL-STD status. References to Chapters II, V, VII and VIII of the Joint Services Human Engineering Guide to Equipment Design as detailed requirements for the traditional "knob and dial" area were dropped in favor of citing HEL STD S-3-65, "Human Factors Engineering Design

Standard for Missile Systems and Related Equipment" (US Army Human Engineering Laboratories, 1965). Some dimensional requirements were adjusted, including reduction in minimum displacement between toggle switch control positions, and increase in minimum pointer depth and minimum pedal size. The anthropometric tables were deleted in favor of referencing HEL STD-S-3-65 and provisions were added for gross, limiting and adjustable dimensions and other data; e.g., use by specialized populations. Acoustic noise was divided into three categories—maximum levels, noise limits for electrically aided communication, and noise limits for direct communication. In other environmental workspace provisions, minimum ventilation air velocity was raised from 15 feet per minute to 65-100 feet per minute, a maximum illuminance at work surfaces was added and some minor changes to interior color and finish provisions were made. Of the five source/guidance documents cited by Notice 1, three were carried over from ABMA-STD-434.

Navy Standards

By the mid-1960's, general military standard human engineering design criteria were represented by the MIL-STD-803A series and MIL-STD-1248. The Navy did not produce a military standard for human engineering design, but developed criteria focused on specific applications, as required. The most prominent of these was "Human Factors Design Standards for the Fleet Ballistic Missile Weapon System" (Bureau of Naval Weapons, 1962), published in two volumes. These volumes were extremely detailed and extensive and found their way into general human engineering applications as one of the prominent set of criteria of the day. Examination of this document will disclose a number of criteria treatments, including provisions on visual fields and console design, which influenced both military standards on human engineering and related criteria. Having been published around 1962, "Human Factors Design Standards for the Fleet Ballistic Missile Weapon System" was in use when MIL-STD-803A series (1964-1967) and MIL-STD-1248 (1964-1966) were developed and was in a position to influence those standards, their references and their tri-service successor document.

Tri-Service Consolidation

At about this time, the Department of Defense was studying the possibility of creating a minimum package of human engineering requirements for tri-service use. This study (Chaikin and Chaillet, 1965) was completed 1 October 1965 and structured, as a by-product of its recommendations, a proposed military standard consolidated from MIL-STD-1248, MIL-STD-803A1 and MIL-STD-803A2, titled "Human Engineering Design Criteria for Aerospace/Missile Systems, Equipment and Facilities." As a result of service and industry coordination, the proposed standard became MIL-STD-1472 applicable to all military systems, equipment and facilities. MIL-STD-1472 was intended to merely consolidate the provisions of MIL-STD-803A series and MIL-STD-1248; however, in the process, the format was changed somewhat, additional figures and tables were added, and the section on Anthropometry was significantly expanded. Of the 51 source/guidance documents cited by MIL-STD-1472, 39 were carried over from MIL-STD-803A series, MIL-STD-1248 and their predecessors.

MIL-STD-1472A

MIL-STD-1472A (Department of Defense, 1970) was developed to revise the anthropometric tables, revise criteria for stairs, ladders and ramps, reprepare graphic presentations for controls and incorporate hundreds of incidental changes resulting from inputs

from military and industry users. At the same time, the following new material was incorporated: Whole body access dimensions, CRT signal size, audio display message categories, noise shields for speech transmission equipment, continuous thumbwheel controls, label design for low ambient illumination, console dimensions for sit-stand operators, door and hatch dimensions, personal equipment thermal control, speech interference levels, matrix displays, computer controlled displays, weights for individual items, quantitative criteria for equipment thermal hazards, references for pilot and copilot stations and metric equivalents. Of the 55 cited source/guidance documents, 34 were carried over from the MIL-STD-803A series, MIL-STD-1248 and their predecessors and 11 were carried over from MIL-STD-1472.

MIL-STD-1472B

MIL-STD-1472B (Department of Defense, 1974) was developed to revise the definition of contrast and acoustical noise provisions; complete incorporation of metric equivalents; expand the definition section, provisions for speech intelligibility, the anthropometry section and the operational and maintenance ground vehicle section; and add material on cathode ray tube (CRT) resolution, electrically or optically-generated displays, light emitting diodes, optical projection displays, keyboards, arm/hand/thumb-finger/leg strength, anthropometric data for women and aviators, unusual work positions, radiation, and horizontal push and pull forces. The cited source/guidance document list dramatically expanded to a total of 94 of which 34 were from the pre-MIL-STD-1472 standards, 10 were from MIL-STD-1472 and nine were from MIL-STD-1472A.

MIL-STD-1472B, Notice 1

Notice 1 to MIL-STD-1472B (Department of Defense, 1976) was issued 10 May 1976 to (a) include, where applicable and where data existed, design provisions for female users of military items, (b) relax the one-hand bar minimum dimensions and shape requirements, and (c) relax color requirements to correlate with those specified by MS-91528 (Department of Defense, 1971). The source/guidance documents remained unchanged.

MIL-STD-1472B, Notice 2

Notice 2 to MIL-STD-1472B (Department of Defense, 1978) was directed primarily toward increasing provisions for women through incorporation of applicable results from the recently completed anthropometric survey of Army women. Where appropriate, new comparative data for men were included. The total of the source/guidance documents expanded slightly to 98 resulting from citing nine new references while deleting five which had been used in predecessor standards. MIL-STD-1472 with Notices 1 and 2 constitute the current issue of "Human Engineering Design Criteria for Military Systems, Equipment and Facilities."

WHY CONSULT OBSOLETE STANDARDS?

Now that the sequence of human engineering military standards has been noted, along with some discussion of the more prominent changes, we can now consider the value of obsolete standards for evaluating human engineering design criteria development as a consideration for tailoring, exception or waiver efforts. An important consideration when one considers relevance of a human engineering design provision to system performance requirements is the basis upon which the design provision was adopted by the governing military standard. As noted before, the following aspects of this consideration can be a vital determinant in the tailoring process:

a. Original intent.

b. Validity of source data for the system.

c. Criteria compromised in the interest of user harmony as an indicator of flexibility.

d. Comparison of older dimensional (and other) requirements against the most recent anthropometric surveys (and other research).

e. Changes to original minima and maxima as a function of rounding metric conversions.

TRACKING HUMAN ENGINEERING PROVISIONS

The first step in tracing a human engineering provision of MIL-STD-1472B is to identify the earliest ancestor document in which the provision appeared. If one has access to the obsolete standards listed in Figure 1, this is a simple backtracking exercise. In many instances, correlation of similar paragraphs between standards is as readily identified as those between issues of the same standard. This process leads one to one of the two subsequent steps. If the design requirement has been changed since its initial appearance, the original intent and that of the change can usually be compared. Conversely, if the re-requirement has not significantly changed since its initial appearance, its source document can usually be identified for evaluation of the basic data upon which the design provision was based. The following two examples illustrate each of these instances and their value to tailoring of standard human engineering provisions.

Example: Original Intent of Provision

Paragraph 5.9.11.5.1 of MIL-STD-1472B states, "All removable or carried units designed to be removed and replaced shall be provided with handles or other suitable means for grasping, handling, and carrying (where appropriate, by gloved or mittened hand)." This paragraph, at first glance, appears to be a fairly firm general provision; however, as with most qualitative requirements in a standard, there is some leeway for interpretation. For example, a designer can interpret that handling aids are required only if the unit is designed, by intent, for removal and replacement (even though it could be removed, repaired and reinserted, rather than replaced). Another designer, and perhaps a human factors specialist, might interpret the requirement to mean that any item which can be removed should have designed-in handholds.

If we trace this provision back through MIL-STD-1472's ancestors, we find that the identical provision existed in MIL-STD-1472A and, without the parenthetical note regarding handwear, in MIL-STD-1472 and in MIL-STD-803A1; however, if MIL-STD-1248 is consulted, the requirement reads as follows: "Assemblies weighing more than ten pounds should have convenient handles to assist in removal, replacement, and carrying."

What we see here is a provision of a standard being selected for a descendent document on the basis of general application by a functional requirement to remove a specified level of equipment—a unit. While the difference between units and assemblies can be significant, we have at least learned that one of the original criteria was based on the weight of the item and can consider this as a meaningful rationale for evaluating the requirement.

Example: Criteria Sources

Another example of tracing human engineering design criteria for assessing applicability for tailoring to a specific application can be found in the control design criteria offered by MIL-STD-1472B. Much of the material in paragraphs 3.5.4.2 and 5.4.3 can be traced back through the MIL-STD-803 series and MIL-STD-1248 to such original standards as AFBM Exhibit 57-8A and ABMA-STD-434. The latter standard identifies the source of the criteria in the cited paragraphs as "Design of Controls, Chapter VI of the Joint Services Guide to Equipment Design" (Ely, Thomson and Orlansky, 1956). Part 3 of that report, detailed design recommendations for specific controls, presents the following preamble (in upper case) to the design recommendations:

> "CAUTION: MOST OF THE VALUES RECOMMENDED IN THIS PART ARE BASED UPON THE AUTHORS' JUDGMENTS AND OBSERVATIONS RATHER THAN AS PUBLISHED RESEARCH. THEY ARE OFFERED AS GENERAL GUIDES AND ARE BELIEVED TO BE APPLICABLE FOR MOST NORMAL OPERATING CONDITIONS. UNDER SPECIAL CIRCUMSTANCES, SUCH AS THOSE CAUSED BY UNUSUAL ENVIRONMENTAL CONDITIONS, OTHER VALUES MAY BE MORE APPROPRIATE."

Comparison of the design recommendations of "Design of Controls" to those appearing in MIL-STD-1472B show extremely faithful use of the recommendations in the form of requirements. Naturally, some of the values have been changed and a significant amount of additional material has been added. While these criteria have withstood the test of time, the important point which should be kept in mind is that much of the current criteria are rounded numbers and their origin is not immersed in research involving legions of test subjects.

If one can trace back a specific provision to a judgment or expert opinion citing a round number as a design limit, it would appear to provide a rationale for tailoring the provision if an insignificant difference is involved between the value specified and one which would be more economical to use or if unusual conditions suggest deviation in the interest of system performance. It is obviously more sensible to accept a control requiring an applied force of 31 pounds, rather than rejecting it out of hand and requiring redesign merely because the standard required a maximum of 30 pounds. On the other hand, a difference of one pound against a minimum force requirement of say, two pounds, could likely be cause for rejection or redesign.

Metrication Effects

To accurately cite examples, we have used customary units of measure up to this point. MIL-STD-1472 contains metric equivalents and, in the near future, will be written around the metric system. In computing metric equivalents for MIL-STD-1472, it has been necessary to round the numbers for convenience of the user of the standard, keeping in mind some of the inherent rounding undertaken when the original criteria were formulated. Typically, such rounding has resulted in differences of only a few percent; however, numerous complaints have been aimed at failure to use exact equivalents out to a half-dozen decimal places. This is the type of doctrinaire use of MIL-STD-1472 and other standards which typifies unreasonable rigidity in prescribing and utilizing design requirements. In any case, one should keep number system conversions in mind as an additional consideration when assessing provisions in future metricated issues of MIL-STD-1472.

CONCLUSIONS

—The use of human engineering design criteria should be predicated upon the degree to which it relates to system performance requirements.

—Most of the requirements in MIL-STD-1472 have been drawn from performance-oriented research and principles and, on this basis, are suitable for use, providing they reflect minimum essential or contingency requirements.

—The days of rigid adherence to all human engineering (and other) design criteria "to the nearest millimeter" irrespective of application validity and practical considerations, are over.

—It is incumbent on both requiring and performing organizations' human factors engineering specialists, when prescribing human engineering design criteria for different program phases and formulating plans for compliance, to exercise discretion and flexibility to insure that design requirements are consistent with selective application and tailoring objectives.

—To accomplish these objectives, the application and the human engineering design provision should be evaluated.

—The design provision can be evaluated on the basis of both the source data originally used to specify the requirement and changes occurring during the development of the human engineering standard over the years.

—To this end, consulting the predecessor documents of and guidance documents listed in the current human engineering design standard can pay handsome dividends.

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